

Energy-Efficient Windows

Windows bring light, warmth, and beauty into buildings and give a feeling of openness and space to living areas. They can also be major sources of heat loss in the winter and heat gain in the summer. The U.S. Department of Energy estimates that 25 percent of the heating and cooling in the United States is lost through windows each year. However, when properly selected and installed, windows can help minimize a home's heating, cooling, and lighting costs. The South Carolina Energy Code requires that double-pane windows or single-pane windows with a storm window be used on all residential buildings. Proof of compliance may also be shown using the CABO Model Energy Code (MEC) software if single pane windows are used without storm windows. Your builder or architect should have the necessary software.

This publication describes two options, energy-efficient windows and window glazing materials, available for reducing a home's heating and cooling energy requirements.

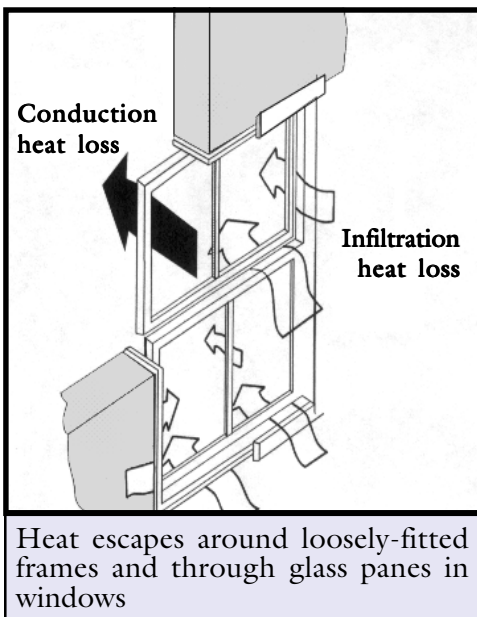
Controlling Air Leaks

When air leaks around windows, energy is wasted. Energy is also transferred through the centers, edges, and frames of windows. Eliminating or reducing these paths of heat flow can greatly improve the energy efficiency of windows and, ultimately, of homes. Several options are available to reduce air leaks around windows; the least expensive options are caulking and weatherstripping, followed by replacing window frames.

Caulking and Weatherstripping

Caulks are airtight compounds (usually latex or silicone) that fill cracks and holes. Before applying new caulk, old caulk or paint residue remaining around a window should be removed using a putty knife, stiff brush, or special solvent. After old caulk is removed, new caulk can then be applied to all joints in the window frame and the joint between the frame and the wall. The best time to apply caulk is during dry weather when the outdoor temperature is above 45° Fahrenheit (7.2° Celsius). Low humidity is important during application to prevent cracks from swelling with moisture. Warm temperatures are also necessary so the caulk will set properly and adhere to the surface.

Weatherstripping is a narrow piece of metal, vinyl, rubber, felt, or foam that seals the contact area between the fixed and movable sections of a window joint. It should be applied between the sash and the frame, but should not interfere with the operation of the window. For more information on caulking and weatherstripping, contact the South Carolina Energy Office.



Replacing Window Frames

The type and quality of the window frame usually affect a window's air infiltration and heat loss characteristics.

Many window frames are available - all with varying degrees of energy efficiency. Some of the more common window frames are fixed-pane, casement, double- and single-hung, horizontal sliding, hopper, and awning.

When properly installed, **fixed-pane** windows are airtight and inexpensive and can be custom designed for a wide variety of applications. But, because they cannot be opened, fixed-pane windows are unsuitable in places where ventilation is required.

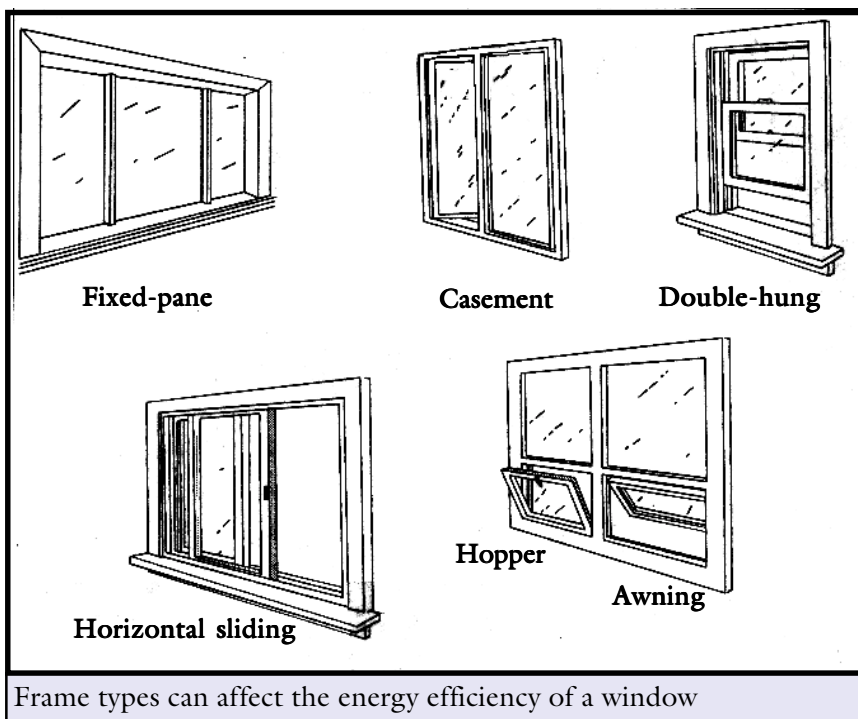
Casement, awning, and hopper windows with compression seals are moderately airtight and provide good ventilation when opened. **Casement** windows open sideways with hand cranks. **Awning** windows are similar to casement windows except that their hinges are located at the tops of the windows instead of at the sides. **Hopper** windows are inverted versions of awning windows with their hinges located at the bottom. Windows with compression seals allow about half as much air leakage as double-hung and horizontal sliding windows with sliding seals.

Double-Hung windows have top and bottom sashes (the sliding sections of the window) and can be opened by pulling up the lower sashes or pulling down the upper sash. Although they are among the most popular type of window, double-hung windows can be inefficient because they are often leaky. Single-hung windows are somewhat better because only one sash moves.

Horizontal Sliding windows are like double-hung windows except that the sashes are located on the left and right edges rather than on the tops and bottoms. Horizontal sliding windows open on the side and are especially suitable for spaces that require a long, narrow view. These windows, however, usually provide minimal ventilation and, like double-hung windows, can be quite leaky.

Reducing Heat Loss and Condensation

Manufacturers usually represent the energy efficiency of windows in terms of their U-values (conductance of heat) or their R-values (resistance to heat flow). If a window's R-value is high, it will lose less heat than one with a lower R-value. Conversely, if a window's

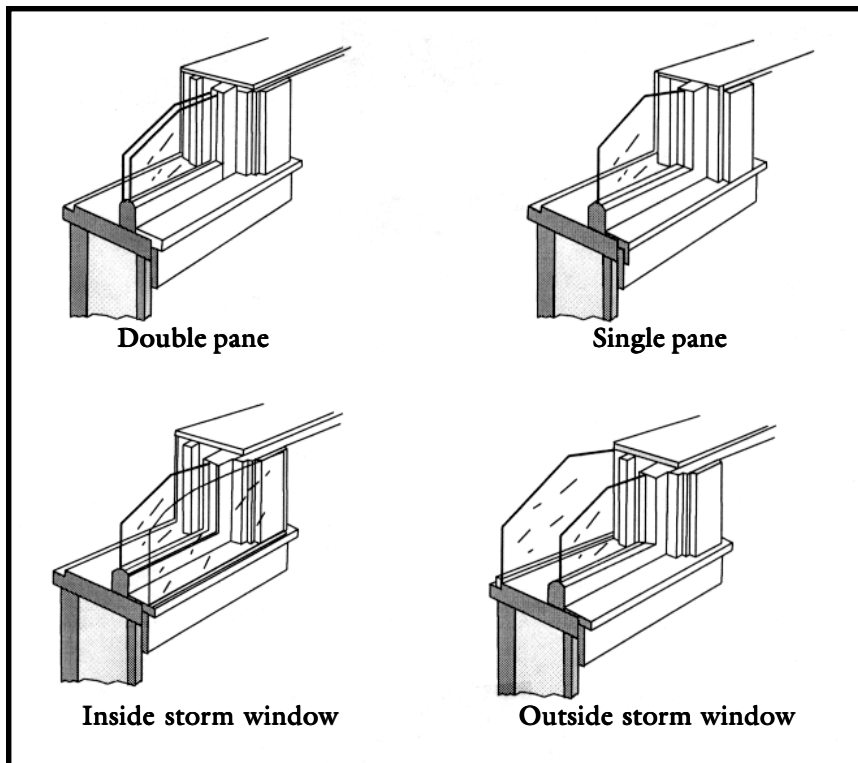


U-value is low, it will lose less heat than one with a higher U-value. In other words, U-values are the reciprocals of R-values ($U\text{-value} = 1/R\text{-value}$). Most window manufacturers use R-values in rating their windows.

Usually, window R-values range from 0.9 to 3.0 (U values range from 1.1 to 0.3), but some highly energy-efficient exceptions also exist. When comparing different windows, you should ensure that all U- or R-values listed by manufacturers: (1) are based on current standards set by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), (2) are calculated for the entire window, including the frame, and not just for the center of the glass, and (3) represent the same size and style of window.

The following five factors affect the R-value of a window:

- * The type of glazing material (e.g., glass, plastic, treated glass)
- * The number of layers of glass
- * The size of the air space between the layers of glass
- * The thermal resistance or conductance of the frame and spacer materials
- * The "tightness" of the installation (i.e., air leaks).



Double-pane windows are usually more efficient than single-pane or storm windows

Types of Glazing Materials

Traditionally, clear glass has been the primary material available for window panes in homes. However, in recent years, the market for glazing - or cutting and fitting window panes into frames - has changed significantly. Now several types of special glazings are available that can help control heat loss, heat gain and condensation.

Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer through the window. These coatings reflect from 40% to 70% of the heat that is normally transmitted through clear glass, while allowing the full amount of light to pass through.

The coatings are thin, almost invisible metal oxide or semiconductor films that are placed directly on one or more surfaces of glass or on plastic films between two or more panes. The coatings typically face air spaces within windows and reduce heat flow between the panes of glass.

When applied inside a double-pane window, the low-e coating is placed on the outer surface of the inner pane of glass to reflect heat back into the living space during the heating season. This same coating

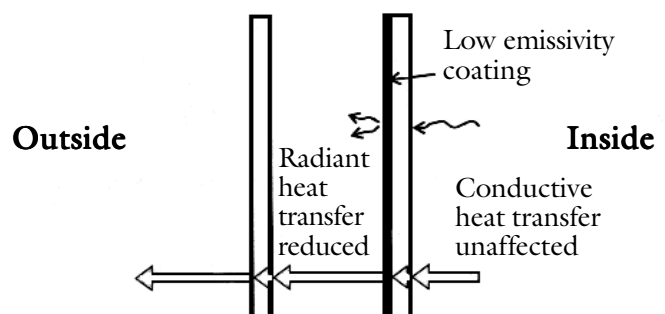
will slightly reduce heat gain during the cooling season.

Low-e films are applied in either soft or hard coats. Soft-coat low-e films degrade when exposed to air and moisture, are easily damaged, and have a limited shelf life, so they are carefully applied by manufacturers in insulated multiple-pane windows. Hard low-e coatings, on the other hand, are more durable and can be used in add-on (retrofit) applications. But the energy performance of hard-coat low-e films is slightly poorer than that of soft-coat films. Windows manufactured with low-e films typically cost about 10% to 15% more than regular windows, but they reduce energy loss by as much as 30% to 50%.

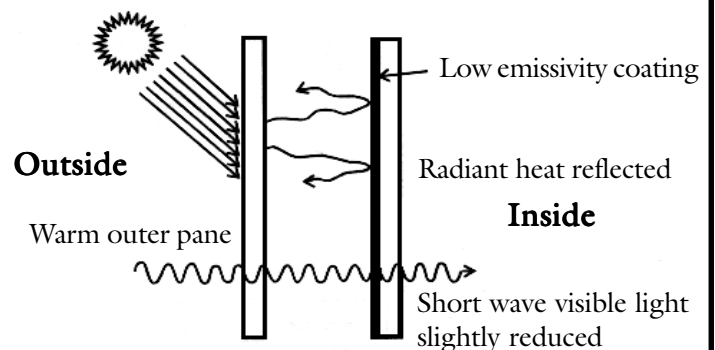
Although low-e films are usually applied during manufacturing, retrofit low-e window films are also widely available for do-it-yourselfers.

These films are inexpensive compared to total window replacements, last 10 to 15 years without peeling, save energy, reduce fabric fading, and increase comfort.

A. Reduced Winter Heat Loss



B. Reduced Summer Heat Gain



Low-e glazings reduce radiant heat transfer

Heat-absorbing glass contains special tints that allow it to absorb as much as 45% of the incoming solar energy, reducing heat gain. Some of the absorbed heat, however, passes through the window by conduction and reradiation. But inner layers of clear glass or spectrally selective coatings can be applied with tinted glass to further reduce this heat transfer. Heat-absorbing glass reflects only a small percentage of light and therefore does not have the mirror-like appearance of reflective glass.

Gray- and bronze-tinted windows reduce the penetration of both light and heat into buildings in equal amounts (i.e., not spectrally selective) and are the most common tint colors used. On the other hand, blue- and green-tinted windows offer greater penetration of visible light and slightly reduced heat transfer compared with other colors of tinted glass. When windows transmit less than 70% of visible light, plants inside could die or grow more slowly. South Carolina is considered to be in a hot and humid climate, therefore black-tinted glass should be avoided because it absorbs more light than heat.

Reflective glass greatly reduces the transmission of daylight through clear glass. Although they typically block more light than heat, reflective coatings, when applied to tinted or clear glass, can also slow the transmission of heat. Reflective glazings are commonly applied in hot climates in which solar control is critical; however, the reduced cooling energy demands they achieve can be offset by the resulting need for additional electrical lighting.

Plastic glazing materials - acrylic, polycarbonate, polyester, polyvinyl fluoride, and polyethylene - are also widely available. Plastics can be stronger, lighter, cheaper, and easier to cut than glass. Some plastics also have higher solar transmittance than glass. However, plastics tend to be less durable and more susceptible to the effects of weather than is glass.

Storm windows can increase the efficiency of single pane windows, the least energy-efficient type of glazing. The simplest type of storm window is a plastic film taped to the inside of the window frame. These films are usually available in prepackaged kits. Although plastic films are easily installed and removed, they are easily damaged and may reduce visibility. Rigid or semirigid plastic sheets such as plexiglass, acrylic, polycarbonate, or fiber-reinforced polyester can be fastened directly to the window frame or mounted in channels around the frame - usually on the outside of the building. These more durable materials are also available in kits.

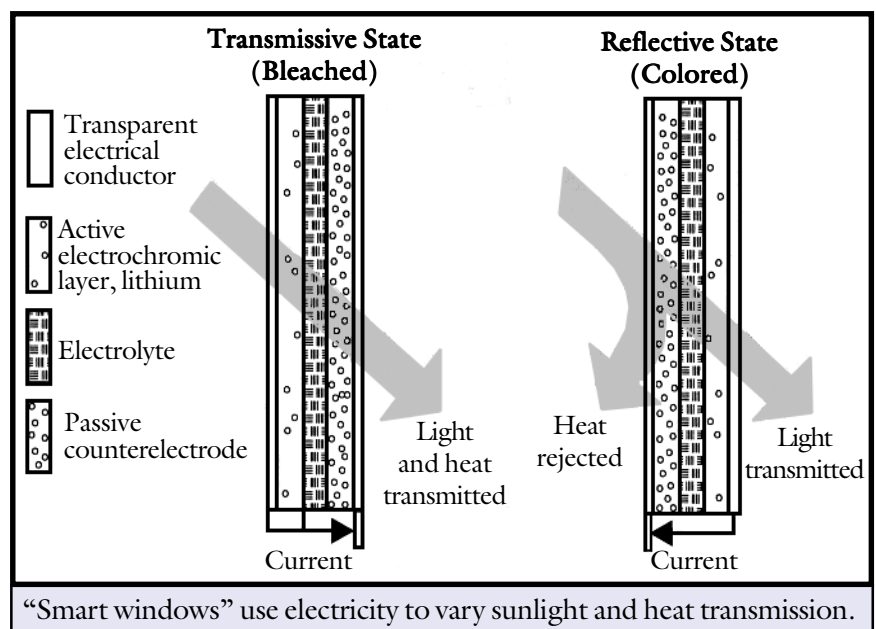
“Futuristic” Options for More Efficient Windows

“Superwindows” now on the market can attain high thermal resistance by combining multiple low-e coatings; low-conductance gas fills; barriers between panes, which reduce convective circulation of the gas fill; and insulating frames and edge spacers.

Also, optical properties such as solar transmittance can be customized for specific climate zones. The heat from even a small amount of diffuse winter sunlight will convert these super-windows into net suppliers of energy. This first generation of superwindows now available have a center-of-glass R-value of 8 or 9, but have an overall window R-value of only about 4 or 5 because of edge and frame losses.

Also under development are chromogenic (optical switching) glazings that will adapt to the frequent changes in the lighting and heating or cooling requirements of buildings. These "smart windows" will be separated into either passive or active glazing categories.

Passive glazings will be capable of varying their light transmission characteristics according to changes in sunlight and their heat transmittance characteristics according to ambient temperature swings. Active windows will use a small electric current to alter their transmission properties.



Layers of Glass and Air Spaces

Standard single-pane glass has very little insulating value (approximately R-1). It provides only a thin barrier to the outside and can account for considerable heat loss and gain. Traditionally, the approach to improve a window's energy efficiency has been to increase the number of glass panes in the unit, because multiple layers of glass increase the window's ability to resist heat flow.

Double- or triple-pane windows have insulating air- or gas- filled spaces between each pane. Each layer of glass and the air spaces resist heat flow. The ideal width of air spaces is between 1/2 and 5/8 inches. The width of the air spaces between the panes is important, because air spaces that are too wide (more than 5/8 inch or 1.6 centimeters) or too narrow (less than 1/2 inch or 1.3 centimeters) have lower R-values (i.e., they allow too much heat transfer). Advanced, multi-pane windows are now manufactured with inert gases (argon or krypton) in the spaces between the panes because these gases transfer less heat than does air.

Multi-pane windows are considerably more expensive than single-pane windows and limit framing options because of their increased weight.

Frame and Spacer Materials

Window frames are available in a variety of materials including aluminum, wood, vinyl, and fiberglass. Frames may be primarily composed of one material, or they may be a combination of different materials such as wood clad with vinyl or aluminum-clad wood. Each frame material has its advantages and disadvantages.

Though ideal for strength and customized window design, **aluminum frames** conduct heat and therefore lose heat faster and are prone to condensation. Through anodizing or coating, the corrosion and electro-galvanic deterioration of aluminum frames can be avoided. Additionally, the thermal resistance of aluminum frames can be significantly improved by placing continuous insulating plastic strips between the interior and exterior of the frame.

Wood frames have higher R-values, are not affected by temperature extremes, and do not generally promote condensation. Wood frames do require considerable maintenance in the form of periodic painting or staining. If not properly protected, wood frames can swell, which leads to rot, warping, and sticking.

Vinyl window frames, which are made primarily from polyvinyl chloride (PVC), offer many advantages. Available in a wide range of styles and shapes, vinyl frames have moderate to high R-values, are easily customized, are competitively priced, and require very low maintenance. While vinyl frames do not possess the inherent strength of metal or wood, larger-sized windows are often strengthened with aluminum or steel reinforcing bars.

Fiberglass frames are relatively new and are not yet widely available. With some of the highest R-values, fiberglass frames are excellent for insulating and will not warp, shrink, swell, rot, or corrode. Unprotected fiberglass does not hold up to the weather and therefore is always painted. Some fiberglass frames are hollow, while others are filled with fiberglass insulation.

Spacers are used to separate multiple panes of glass within the windows. Although metal (usually aluminum) spacers are commonly installed to separate glass in multi-pane windows, they conduct heat. During cold weather, the thermal resistance around the edge of a window is lower than that in the center; thus, heat can escape, and condensation can occur along the edges. To alleviate these problems, one manufacturer has developed a multi-pane window using a 1/8-inch-wide (0.32 centimeters-wide) PVC foam separator placed along the edges of the frame. Like other multi-pane windows, these use metal spacers for support, but because the foam separator is secured on top of the spacer between the panes, heat loss and condensation are reduced. Several window manufacturers now sandwich foam separators, nylon spacers, and insulation materials such as polystyrene and rockwool between the glass inside their windows.

Additional Options for Reducing Heat Loss and Gain through Windows

Movable insulation, such as insulating shades, shutters, and drapes, can be applied on the inside of windows to reduce heat loss in the winter and heat gain in the summer. Shading devices, such as awnings, exterior shutters, or screens, can be used to reduce unwanted heat gain in the summer.

In most cases, these window treatments are more cost-effective than energy-efficient window replacements and should be considered first. Additional information on window treatments is available from EREC (see Source List on page 6).

Conclusion

Reducing heat loss or gain in homes often includes either improving existing windows or replacing them. Low-cost options available for improvement are caulking, weatherstripping, retrofit window films, and window treatments. Replacing windows will involve the purchase of new materials, which should adhere to certain energy efficiency standards.

Different combinations of frame style, frame material, and glazing can yield very different results when weighing energy efficiency and cost. For example, a fixed-pane window is the most air-tight and the least expensive; a window with a wood frame is likely to have less conductive heat loss than one with an aluminum frame; double-pane, low-e window units are just as efficient as triple-pane untreated windows, but cost and weigh less.

No one window is suitable for every application. Many types of windows and window films are available that serve different purposes. Moreover, you may discover that you need two types of windows for your home because of the directions that your windows face and your local climate. To make wise purchases, first examine your heating and cooling needs and prioritize desired features such as daylighting, solar heating, shading, ventilation, and aesthetic value.

Source List

The following organizations and publications provide more information on energy-efficient windows.

**The Energy Efficiency and Renewable Energy
Clearinghouse (EREC):**

P.O. Box 3048
Merrifield, VA 22116
(800) 363-3732
Fax: (703) 893-0400

E-mail: doe.erec@nciinc.com

<http://www.eren.doe.gov/erec/factsheets/factsheets/html>

South Carolina Energy Office

1201 Main Street, Suite 820
Columbia, SC 29201

(803) 737-8030

(800) 851-8899

Fax (803) 737-9846

<http://www.state.sc.us/energy/>

EREC and the SC Energy Office provide free general and technical information to the public on the many topics and technologies pertaining to energy efficiency and renewable energy.

National Fenestration Rating Council (NFRC)

1300 Spring Street, Suite 500
Silver Spring, MD 20910
(301) 589-6372

E-Mail: NFRCUSA@aol.com

<http://www.nfrc.org>

NFRC is a non-profit, public/private organization created by the window, door and skylight industry. It is comprised of manufacturers, suppliers, builders, architects and designers, specifiers, code officials, utilities and government agencies.

National Renewable Energy Laboratory

Electrochromic Windows Research

<http://www.nrel.gov/buildings/windows/>

DOE's Electrochromic Window initiative is facilitating the introduction of cost-effective, durable electrochromic windows. Electrochromic windows offer the potential for automated control of daylight and solar heat gain in buildings and vehicles.

**American Society of Heating, Refrigerating, and
Air-Conditioning Engineers (ASHRAE)**

1791 Tullie Circle, NE
Atlanta, GA 30329

(404) 636-8400

<http://ashrae.org>

ASHRAE's Handbook of Fundamentals contains tables citing heat transfer, light transmittance, and shading properties for various window types and materials.

National Wood Window and Door Association

1400 East Touhy Avenue
Des Plaines, IL 60018-3305
1-800-223-2301

The National Wood Window and Door Association is a trade association representing approximately 130 US and Canadian manufacturers and suppliers of wood windows and doors for domestic and export markets. NWWDA issues seals of approval from manufacturers of wood-framed windows.